

LEVEL II



Cost-Effectiveness Specification for Computer-Based Training Systems

EXECUTIVE SUMMARY

by

**Robert J. Seidel
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September 1977

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ②	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Cost-Effectiveness Specification for Computer-Based Training Systems • Executive Summary		5. TYPE OF REPORT & PERIOD COVERED Research Product
7. AUTHOR(s) ⑩ Robert J./Seidel • Harold/Wagner		6. PERFORMING ORG. REPORT NUMBER
8. PERFORMING ORGANIZATION NAME AND ADDRESS Human Resources Research Organization 300 North Washington Street Alexandria, VA 22314		9. CONTRACT OR GRANT NUMBER(s) ⑮ MDA903-76-C-0210 DARPA Order R-31 87
11. CONTROLLING OFFICE NAME AND ADDRESS Defense Advanced Research Projects Agency 1400 Wilson Boulevard Arlington, VA 22209		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS ⑫ 152
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) 405 260		13. RECORD DATE ⑪ Sep 77
		14. NUMBER OF PAGES 307 pp.
		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) This document has been approved for public release; its distribution is unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES This reports consists of (1) Executive Summary; (2) Volume 1 - Development w/ Workbook; (3) Volume II - Procurement w/Workbook; and (4) Volume III - Operation and Maintenance w/Workbook.		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) computer-based training systems operation and maintenance computer-based training system life cycle cost methodology cost-effectiveness specification effectiveness dimensions development procurement		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) → The purpose of this cost-effectiveness specification is to facilitate the purchase, monitor, and evaluation of computer-based training systems. This standardized structure for deriving and communicating training system costs and effectiveness is presented in three volumes, corresponding to the life cycle of a computer-based training system: (1) development, (2) procurement, and (3) operation and maintenance. The cost methodology focuses on identifying and quantifying total inputs required by the system over its life cycle. Effectiveness dimensions include objectives-based achievement and time measures for within-		

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course and end-of-course criteria. Other measures, such as attrition rates, instructor ratings, and attitude scales, are also discussed.



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This research was supported by the Defense Advanced Research Projects Agency under DARPA Order No. 3187 Contract No. MDA903-76-C-0210.

The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the Defense Advanced Projects Agency.

September 1977

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PREFACE

This is the Executive Summary Volume of the Cost-Effectiveness Specification for Computer-Based Training Systems. This volume provides the reader with general guidance and instructions on how to go through and respond to the various parts of the specification. The remaining three volumes correspond to the three phases of a training system's life cycle (Volume I - Development; Volume II - Procurement; Volume III - Operation and Maintenance). This Cost-Effectiveness Specification was developed for DARPA as part of Contract #MDA903-76-C-0210. Dr. Harold F. O'Neil was the Technical Monitor.

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COST-EFFECTIVENESS SPECIFICATION FOR COMPUTER-BASED TRAINING SYSTEMS

Executive Summary

PURPOSE

The purpose of this cost-effectiveness specification is to facilitate the purchase, monitoring and evaluation of computer-based training systems for DARPA. It provides a standardized structure through which training system costs can be derived and communicated. The specification is oriented toward training which is administered, aided, or managed by computer.

INTRODUCTION

The preparation and analysis of cost and effectiveness estimates are essential activities in the acquisition and management control of computer-based training systems. These activities serve to increase institutional understanding of a system's cost composition and the factors driving costs, as well as an understanding of the system's effectiveness in meeting training requirements.

The cost methodology employed herein is focused on identifying and quantifying the total inputs (men, money, material) required by a computer-based training system throughout its life cycle. The inputs which have been identified are then costed in terms of Development, Procurement, and Operating and Maintenance costs to attain and sustain a training capability over a fixed period of time (i.e., 8 years). All the major cost categories of resources that are required by a computerized training system are then defined and listed. The Training Cost Breakdown Structure (TCBS) serves to specify those elements.

The effectiveness dimensions to be considered by users of this specification include objectives-based achievement and time measures for within-course and end-of-course criteria. Other measures such as attrition rates, instructor ratings, and attitude scales are also discussed. Priorities are not established by this specification except that effectiveness criteria must reflect training requirements. Guidance is provided to the trainer/decision-maker who uses this specification, to weight effectiveness measures according to the training requirements that "drive" the analysis.

WHO IS TO COMPLETE THE SPECIFICATION?

The approach in using this specification involves accumulating cost-effectiveness data separately during the phases of a computer-based training system's life cycle: Development, Procurement, and Operation and Maintenance. Guidance and recording forms applicable to each phase have been placed in

separate volumes. Different individuals or groups of individuals are responsible for completing each of the Volumes of the Specification. In the system's Development Phase (Volume I), it is anticipated that of the contractor personnel only the project director would have access to all the information needed for this specification. Assistance would be needed from one or more individuals to gather all costing and effectiveness data in a form that can be used in this specification. Only the sponsor's technical and/or contracts monitor would be able to access similar information, but would ultimately need to request the data from the contractor. In the Procurement Phase (Volume II), the comptroller or his counterpart employed by the contractor or the sponsor's contract monitor would have access to the necessary information for this specification. In the Operation and Maintenance Phase, the individual located at a school or training site who has access to all the necessary information is the commander or director of the school or his designated training manager.

In each phase, one individual should be given the responsibility for gathering the data and performing the analysis required by this specification. Although this may involve spending resources needed elsewhere, it is the only approach that permits data collection that is consistent with the guidance and formats provided in this specification.

FORMAT OF THIS SPECIFICATION

This cost-effectiveness specification is divided into three volumes--each representing a different phase in the life cycle of a computer-based training system. These life cycle phases are: Development, Procurement, and Operation and Maintenance. The three phases are of variable lengths depending upon each specific system. Although the three phases overlap, for purposes of this specification, they will be considered to occur sequentially. The Development Phase can take up to 6 years, the Procurement Phase is shown as one year, and the Operation and Maintenance Phase can be up to 8 years. Although Procurement can take more than one year, this specification requires an assumption of all Procurement activities occurring within the year following development of a tested prototype system. Also, although such systems are usually phased in, it is assumed in this specification that Procurement will be followed by instantaneous operation of all systems acquired.

- Volume I - Development Phase activities are related to the design and production of a tested, prototype computer-based training system. Development Phase activities include: applied research, engineering design, analysis, development, test, evaluation and management related to a specific computer-based training system.

- Volume II - Procurement Phase activities are related to the production, purchase, and installation of the operational computer-based training system. Included in these activities are: fabrication, communication, reproduction, packaging and shipping, etc. Procurement activities are necessary to transform or copy the tested, prototype system into a fully operational system consisting of the hardware, software, facilities, training, and support necessary to initiate operations.

• Volume III - Operation and Maintenance Phase activities are related to the daily operation and maintenance of the computer-based training system over its projected life after its official acceptance. Operation and Maintenance activities include: replacement training for site personnel, administration, instructional delivery, etc.

Each volume is composed of several parts. These sections are listed below.

Part

- A System Description
- B General Costing Assumptions and Definitions
- C Computer-Based Training System Elements: Definitions and Costs
- D Training Cost Breakdown Structure (TCBS) Matrix
- E Training Effectiveness Assumptions and Definitions
- F Within-Course Training Effectiveness Data
- G End-Of-Course Training Effectiveness Data
- H Cost-Effectiveness Analysis Guidance
- I Cost-Effectiveness Analysis Calculations

Volumes I and III contain all nine parts (A-I), whereas Volume II (Procurement) includes only the parts related to costing (Parts A-D). Each of the parts of the specification are described below.

• Part A - System Description. In this part, a form is presented in which individuals who use the specification are to be identified, and general characteristics of the computer-based training system are to be described.

• Part B - General Costing Assumptions and Definitions. A discussion of the assumptions which underlie the costing approach taken in the specification is presented in this part. In addition, definitions of terms and guidelines related to costing are provided.

• Part C - Computer-Based Training System Elements: Definitions and Costs. In this part costing information is to be provided for each element of the computer-based training system. The elements are categorized and hierarchically arranged in a Training Cost Breakdown Structure (TCBS). Definitions of all system elements are provided with examples of how these items are to be costed. To assist the user in identifying personnel costs, Personnel Cost Worksheets accompany this part of the specification.

● Part D - Training Cost Breakdown Structure (TCBS) Matrix. In this part of the specification, the TCBS is used for entering summary cost data. In Volumes I and III, the TCBS is presented in matrix form in order that yearly costs can be specified. (In the Procurement Phase - Volume II, all costs are presented as having been spent in one year.) The element costs shown in Part C are to be summed for each subcategory and entered into the appropriate row of the TCBS. Total costs by category are to be calculated and then summed to arrive at total Development, Procurement, or Operation and Maintenance costs for each year covered in each Phase of the system's life cycle. The TCBS category and subcategory headings used in Parts C and D are presented below. Costs will be unique to each of the three Phases, but cost categories and subcategories are fairly uniform as can be seen from the following list.

Development Phase

1. Equipment

- 1.1 Computer(s)
- 1.2 Terminal(s)
- 1.3 Auxiliary AV Devices
- 1.4 Auxiliary Memory
- 1.5 Local Interfaces
- 1.6 Telephone Lines
- 1.7 Special Lines
- 1.8 Satellites
- 1.9 Receivers
- 1.10 Power Generating Equipment
- 1.11 Carrels
- 1.12 Other Equipment

2. Facilities

- 2.1 Classrooms
- 2.2 Laboratories
- 2.3 Large Group Instruction Spaces
- 2.4 Offices
- 2.5 Individual Learning Spaces
- 2.6 Libraries and Other Information
Resource Centers
- 2.7 Other Facilities

3. Software

- 3.1 Systems Programs
- 3.2 General Applications Programs
- 3.3 Diagnostic/Test Programs
- 3.4 Utility Programs
- 3.5 Other Computer Programs

4. Instructional System Development

- 4.1 Analyze (Phase I)
- 4.2 Design Phase (Phase II)
- 4.3 Development Phase (Phase III)
- 4.4 Other Instructional System Development (ISD) Activities

5. Instructional Methods/Materials

- 5.1 Audio
- 5.2 Audio/Visual
- 5.3 Film Text/Visual
- 5.4 Lecture/Demonstration
- 5.5 Group Discussion/Seminar
- 5.6 Performance/Practice
- 5.7 Tutoring (Peer or other)
- 5.8 Printed Text/Visual
- 5.9 CAI Materials
- 5.10 Other Instructional Methods/Materials
- 5.11 Tests

6. System Management/Test

- 6.1 System Integration Engineering
- 6.2 Program Management
- 6.3 Operational Test
- 6.4 Other Direct Management Costs

7. Other Direct Costs (not included in the above)

- 7.1 Supplies
- 7.2 Travel
- 7.3 Consultants
- 7.4 Contracts/Subcontracts
- 7.5 Other Direct Costs

Procurement Phase

(same as Development Phase with the following exceptions):

4. Instructional Preparation

- 4.1 Training of Initial Site Personnel Cadre
- 4.2 Site Personnel Pay and Allowances
- 4.3 Other Instructional Preparation Costs

6. Acceptance Test/Management

- 6.1 Program/Project Management
- 6.2 Acceptance Test
- 6.3 Engineering Changes
- 6.4 Site Checkout/Activation
- 6.5 Other Direct Management Costs

Operation and Maintenance Phase

(same as Development Phase with the following exceptions):

1. Equipment

- 1.12 Replacement Spares and Repair Test Equipment
- 1.13 Other Equipment

4. Instructional System Development (ISD) Activities

- 4.1 Implement (Phase IV)
- 4.2 Control (Phase V)
- 4.3 Other Instructional System Development (ISD) Activities

6. System Management

- 6.1 Program/Project Management
- 6.2 Other Direct Management Costs

● Part E - Training Effectiveness Assumptions and Definitions. In this part of the specification, guidance, definitions, and procedures are provided by which the effectiveness of the computer-based training system can be measured. A general discussion of evaluation and effectiveness is followed by definitions of terms. Effectiveness measures are described and procedures recommended for acquiring this information.

● Part F - Within-Course Training Effectiveness Data. In this part of the specification, instructions and recording forms are provided for entering training effectiveness data for each major course Section. Additional forms are provided for weighting and summarizing these data for the entire course. Such summary data are not to be used in evaluating the cost-effectiveness of the system unless end-of-course information is unavailable.

● Part G - End-of-Course Training Effectiveness Data. In this part of the specification, instructions and recording forms are provided for entering data on training effectiveness for the Course as a whole. The headings used on the forms for categorizing the end-of-course effectiveness measures are as follows:

Time Measures

Average Training Time in Course
Average Testing Time in Course
Average Course Time

Achievement Measures (Final Criterion Test Results-First Attempt)

Accuracy or Speed Scores
Gain Scores
Number of Objectives Passed
% Students Passed

Other Effectiveness Measures

Instructor Ratings
Student Attitudes
Attrition Rates
Absentee Rates
Other Measures

Scores on these measures will enter the cost-effectiveness analyses to be performed using the procedures presented in Parts H and I of the specification.

● Part H - Cost-Effectiveness Analysis Guidance. In this part of the specification the approach to be taken in analyzing the cost-effectiveness of computer-based training systems is described. The assumptions which underly this approach are discussed and general guidance is presented for interpreting and applying the findings.

● Part I - Cost-Effectiveness Analysis Calculations. In this part of the specification, instructions and worksheets are provided for calculating the cost-effectiveness ratios which can be used to evaluate a computer-based training system.

APPLYING THIS SPECIFICATION

In Volumes I-III, specific instructions and recording forms are provided for gathering and summarizing the appropriate data needed for evaluating the cost-effectiveness of computer-based training systems. Guidance is also provided in Volumes I and III (Parts H and I) on how to use the data to calculate and interpret the cost-effectiveness ratios and other indices by which to compare alternative training systems. Key points to consider in performing a cost-effectiveness analysis, extracted from these Volumes, are presented on the following pages.

Comparative cost-effectiveness analysis can be reliably performed only when the training system(s) being compared are in their Operation and Maintenance Phase. However, as procurement decisions are often required prior to having the prototype training system reach a steady state of reliability, *projected* cost-effectiveness analyses are performed during the Development Phase. These projections should occur when the prototype system has reached its operational test stage. At that time, the Operation and Maintenance Phase Volume (III) can be used for entering data and making computations. It should be noted that such projections are potentially dangerous as they are subject to error based on the unknown contributions to total system unreliability of the various system components (computer, terminals, communication links, undebugged software and courseware). As the hardware/software base of the system is undergoing validation and reliability checks, debugging, etc., during the Development Phase, training effectiveness data can be unduly influenced by factors which would not be present in the operational system.

Thus, the user of this specification for systems in their Development Phase (Volume I) should treat *projected* cost-effectiveness ratios as tentative predictions subject to many sources of error. Although the results of these analyses in the Operation and Maintenance Phase (Volume III) are also *estimates*, they are based on findings which are derived from a more stable and reliable data base.

When comparisons are to be made of alternative training systems, or of media within a course, cost-effectiveness evaluation is meaningful only if training objectives, content, testing conditions and criteria are similar. To make judgments of cost-effectiveness without holding these items constant can lead to erroneous decisions.

The effectiveness of a computer-based training system can be attributed to its instructional technology if the effectiveness measures are tied to those portions of the course that are supported by this technology. Otherwise, you cannot draw any conclusions related to the cost-effectiveness of that technology.

The user of this specification should make sure that the criteria set for evaluating cost-effectiveness are based on the training requirements imposed on the system. These criteria should be established by the appropriate decision-maker who should also assign priorities to the various dimensions of training effectiveness--weightings of importance which should reflect training requirements and goals.

Cost-effectiveness of a computer-based system may also be determined by its relative efficiency in aiding in the development and dissemination of primary and auxiliary training materials. This is perfectly acceptable as long as the decision-maker understands that these evaluation criteria are to be applied independently, whether or not the system is used for training. Many computer-managed instruction (CMI) systems, for example, could be evaluated solely in terms of their relative adequacy for developing materials, scheduling equipment usage, and record-keeping.

However, if training effectiveness is of primary importance, such efficiency indices should not be substituted for achievement measures.

The last guideline to be described here relates to fixing cost or effectiveness criteria. The decision-maker calculates the cost-effectiveness ratio of a system by: (a) fixing operating costs and evaluating the system on its training effectiveness (e.g., achievement scores, number of objectives mastered, etc.); or (b) fixing level of effectiveness and evaluating the system on how much it costs to attain this level in an operational environment. If both costs and effectiveness levels are allowed to vary together, difficulties arise in determining the value of any additional benefits. Also, such an approach leads to the false expectation that there exists a maximally effective system with a minimal cost. Only if costs are fixed can one look for the most effective training system. Or, if levels of effectiveness are established, can the training system which costs the least be selected as most cost-effective.